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# **Newer Methods for Selection of Patients for Lumbar Sympathectomy**

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### SUMMARY

The degree of vasodilatation achieved by various diagnostic methods (arterial occlusion, ganglionic block established by certain agents, lumbar sympathetic block, spinal anesthesia, and indirect heating) was studied by means of the pneumo-plethysmogram as well as through readings of skin temperature and skin resistance. The data obtained were interpreted as to their value in determining the type of patient with vascular disease for whom lumbar sympathectomy would be of noticeable benefit. Arterial occlusion proved itself a rapid and simple method which in most patients produced satisfactory results. As a rule, lumbar sympathectomy was effective in patients who preoperatively had shown a positive response upon release of arterial occlusion. A negative response, that is, absence of significant increase in blood flow, does not necessarily indicate organic

disease, and cannot be taken to mean that lumbar sympathectomy would always be ineffective. Ganglionic block, using 2.6 dimethyl piperidinium bromide or tetraethylammonium ion, was generally less reliable in indicating the probable results of sympathectomy than lumbar sympathetic block or indirect heating. Lumbar sympathetic block with procaine was followed by a greater increase in skin temperature and blood flow than spinal anesthesia, and permitted far more accurate conclusions as to the probable outcome of sympathectomy. Subsequent to indirect heating the plethysmogram showed characteristic differences depending on the degree of vascular disease present. From the effect of this simple, safe and painless method upon the relative blood flow to the toe it becomes possible to arrive at a comparatively accurate estimate of the clinical benefit to be expected from lumbar sympathectomy.

THE importance of lumbar sympathectomy as a surgical procedure for the treatment of selected patients with peripheral vascular disease is by now fully recognized. This operation, however, does not in all instances lead to uniformly good results, and certain patients show no significant improvement while in others even an exacerbation of the disease can be noted. It is the purpose here to discuss certain diagnostic methods which have proved helpful in a proper selection of patients for lumbar sympathectomy.

The present report is based on a study of 150 unselected cases; the youngest of the patients was 18 years of age, the oldest 78; the average age was 48 years. All experiments were conducted in a constant temperature room with a temperature of 25° C.  $\pm$  1.5°. The conditions of these studies were rigidly controlled and have been described elsewhere.11

Various methods of investigation were employed simultaneously, including a study of vasomotor reactions and blood flow2, 3 by means of the pneumoplethysmograph; continuous readings of skin temperatures were taken with an electronic recorder, and sweating was measured with a dermometer. 6, 7, 8, 10 Vasomotor changes resulting from application of one or several of the following test methods were noted: (1) arterial occlusion; (2) blocking of the autonomic ganglia by certain chemical agents; (3) lumbar sympathetic block; (4) spinal anesthesia, and (5) indirect heating.

Of the total number of subjects examined, 52 were normal, while in 98 peripheral vascular disease was found to be present. In this latter group arteriosclerosis obliterans was noted in 86 per cent and thromboangiitis obliterans in 14 per cent. On the basis of clinical observations and independent of the precise nature of the vascular involvement, two sub-groups were established: In 60 patients (of a total of 98) arterial disease was described as moderate, without ulceration of the digits; in the remaining 38, pronounced arterial disease with ulceration was observed.

Lumbar sympathectomy was performed in 25 instances, and the patients were observed before as well as after operation; the diagnosis in 16 cases was moderate and in eight cases pronounced arterial disease; and in one case it was hereditary lymphedema without arterial disease. In all instances of lumbar sympathectomy at least the second and third lumbar ganglia were removed.

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Angeles.

Presented as part of a Symposium on Heart Disorders arranged jointly by the Section on General Medicine and the Medical Division of the California Heart Association at the 78th Annual Session of the California Medical Association, Los Angeles, May 8-11, 1949.

Gratitude is expressed to Dr. B. O. Raulston for the encouragement and cooperation extended during these studies

Several methods for the determination of the degree of vascular disease were tested in order to establish their reliability as indicators of the benefit which may be expected from lumbar sympathectomy. Arterial occlusion was performed in half the number of all individuals studied, whenever feasible for a period of 15 minutes; in many cases, however, it proved impossible, on account of the patient's condition, to apply this method longer than five minutes. Of 75 subjects, 52 had arteriosclerosis obliterans or thromboangiitis obliterans of the extremity, while the remaining 23 were normal. Two patients suffered injury at the site of arterial occlusion, and in an equal number the test could not be completed by reason of pain caused by the procedure. In all 25 instances in which lumbar sympathectomy had been performed the effect of arterial occlusion was studied seven to 14 days after the operation.

The following technique was employed in order to produce arterial occlusion: The patient was placed in the supine position and the limb was elevated for 30 seconds. A blood pressure cuff was applied above the knee and inflated to 60 mm. of mercury above systolic pressure. The limb was then returned to the horizontal position. After five or possibly 15 minutes the cuff was suddenly released. The blood flow of the toe was recorded every 15 seconds until a maximum flow was reached. This method is simple as well as efficient, but the data obtained will prove reliable only if the test is conducted under ideal experimental conditions, because a startling sound, pain, anxiety, and chilling of body surfaces are apt to decrease the flow of blood.

On the basis of observations following arterial occlusion for a period of five minutes, three types of reactions could be distinguished; in normal subjects the total blood flow increased rapidly after the occluding cuff had been released, and only little change in the skin temperature of the toe was observed. Among patients with moderate vascular disease the same response occurred, yet to a lesser degree. Among those with pronounced vascular disease little or no change occurred in either blood flow or skin temperatures. When the skin temperature changes were compared with changes in blood flow following release of the arterial occlusion it was apparent that definite increases in blood flow were usually accompanied by insignificant increases in skin temperature. Thus the plethysmographic method of evaluating the effects of arterial occlusion was much more sensitive than the measurement of skin temperature.

An increase in blood flow following arterial occlusion suggests that lumbar sympathectomy would be beneficial; in cases in which this diagnostic method, properly performed, results in only a small increase of the flow or fails to have any effect, it has been concluded that the operation would be of questionable benefit.

Exceptions to this rule are patients who have intense vasospasm not accompanied by any signs of

organic vascular disease. In these cases arterial occlusion may be followed by only a small increase in the blood flow while, on the other hand, lumbar sympathetic block as well as lumbar sympathectomy result in a definite increase of the blood flow.

In the 24 patients with arterial disease who were subjected to lumbar sympathectomy the rate of blood flow obtained preoperatively through arterial occlusion of five minutes' duration was compared to that established seven to 14 days after operation. It was found that in four cases the rate had increased, while in 16 others the figures were unchanged, and in the remaining four the blood flow was postoperatively lower than preoperatively. Similarity of the figures resulting from preoperative arterial occlusion and observations following lumbar sympathectomy may, however, be due to different physiologic processes: Release of the occlusion cuff may produce an increase in flow to the deeper tissues of the digit, while lumbar sympathectomy may result in an increased flow to the skin.9

Arterial occlusion has been made the basis of another clinical method of determining the degree of vascular disease in a limb. Less time elapses in healthy limbs before the extremity becomes erythematous after release of the cuff than when organic disease is present. It is, however, difficult to time accurately the appearance of erythema following release of the cuff, and in the present study this method was therefore not considered reliable in estimating the effect of sympathectomy.

Ganglionic block was produced in 15 subjects in order to observe the peripheral vascular effect of this procedure and to evaluate its usefulness in the selection of patients for lumbar sympathectomy. The quaternary amine, SC 1950 (2.6 diethyl piperidinium bromide) \* was employed in all instances, and in some cases an additional test was made with tetraethylammonium ion (Etamon®). 1. 4 SC 1950 was administered by slow intravenous injection, the dose amounting to 0.5 mg. per kilogram of body weight.

In nine of these 15 cases it was possible to examine the patient seven to 14 days after lumbar sympathectomy, and thus to compare the postoperative values with the data obtained through preoperative ganglionic block. In this sub-group the diagnosis in eight instances was advanced arteriosclerosis obliterans, while in one instance it was early thromboangiitis obliterans. Upon ganglionic block the skin temperature of the toes rose in this last mentioned patient from 28° to 34° C., and the corresponding total blood flow increased from 1.0 to 8.0 cu. mm. per 5 cc. per second. These observations suggested that lumbar sympathectomy would be of value in this case, and definite clinical improvement followed the surgical procedure. Fourteen days postoperatively the skin temperature was 34.5° and the blood flow 10 cu. mm. per 5 cc. per second. All eight patients with advanced obliterative arterio-

<sup>\*</sup> Furnished by Research Laboratories, G. D. Searle & Co.

sclerosis of the limb showed also greater increase in skin temperature as well as in blood flow seven to 14 days after sympathectomy than they had shown following injection with SC 1950. The increase following preoperative ganglionic block produced by tetraethylammonium ion (Etamon) was similarly lower than the postoperative readings.

The peripheral vascular effect of blocking of the autonomic ganglia with SC 1950 or Etamon is smaller than that immediately following lumbar sympathectomy. This finding may be explained through the fact that ganglionic block results in generalized vasodilatation, and the blood is thus shunted away from the diseased limb.<sup>5</sup>

It may be advisable to report concomitantly on the diagnostic value of lumbar sympathetic block and of spinal anesthesia, using procaine. Forty patients with arteriosclerosis obliterans were studied by either the one or the other of these methods.

Lumbar sympathetic block was produced by introducing one, two or three needles in the region of the second, third or fourth lumbar ganglia, and 10 cc. of a 2 per cent procaine solution was injected at one or all of these sites. This procedure is reasonably painless and leads in the majority of cases to satisfactory results. It is, however, advisable to perform lumbar sympathetic block in the clinic or the hospital, as the danger of infection, neuritis, and various reactions to procaine can never be entirely excluded.

Dryness of skin occurring within 10 or 20 minutes after injection was taken as a sign that the block had been successfully established. Blood flow to the skin was estimated from the skin temperature and digital flow recorded in the plethysmogram. Readings of the dermometer proved of considerable value, as the absence of sweat following procaine injection signified a lowering of the skin resistance and indicated in turn that infiltration of the sympathetic ganglia had been achieved.

A submaximal increase in the skin temperature as well as of the peripheral flow following lumbar sympathetic block constitutes evidence suggestive of organic arterial disease. In ten instances, lumbar sympathectomy was subsequently performed, and it was thus possible to compare the results of preoperative lumbar sympathetic block with the effects of operation, seven to 30 days after operation. It developed that in all those cases in which the lumbar sympathetic block was not followed by a significant fall in systemic blood pressure, the measurements of blood flow as well as the readings of skin temperature were similar subsequent to lumbar sympathetic block and following lumbar sympathectomy.

Spinal anesthesia was studied in five patients who later were subjected to lumbar sympathectomy, but its diagnostic value proved to be inferior to that of lumbar sympathetic block. Spinal anesthesia effected by slow injection of 100 mg. of procaine, was performed by a trained anesthetist, and a satisfactory level of skin anesthesia resulted in all cases. However, rise in skin temperature and blood flow of the

affected limb as well as the amplitude of pulsation as recorded in the plethysmogram were far less pronounced than following satisfactory lumbar block.

This relatively poor effect of spinal anesthesia upon the blood flow in the toe can in all probability be traced to vasodilatation in both lower extremities combined with a fall of the systemic blood pressure. Such an effect is obviously less desirable than vasodilatation restricted to a single limb, while at the same time the systemic blood pressure remains at the pre-injection level.

The following experiment may exemplify the limited degree to which spinal anesthesia produces vasodilatation. A patient with partial occlusion of the femoral artery had an initial rate of blood flow in the toe of 0.5 cu. mm. per 5 cc. per second. After spinal anesthesia the rate of flow doubled. Ganglionic block using SC 1950 reduced the flow to 0.1 cu. mm. per 5 cc. per second, a fact probably due to the so-called borrowing-lending phenomenon. Lumbar sympathetic block produced a rise of blood flow to 2.5 cu. mm. per 5 cc. per second, while following arterial occlusion of five minutes' duration the flow increased to 3.5 cu. mm.

### INDIRECT HEATING

A new method for the selection of patients for lumbar sympathectomy has been developed at the Nash Cardiovascular Foundation. It is an established fact that heat exerts a definite influence upon the blood flow to the extremities. Yet, up to the present the effects of body heating have usually been recorded by measuring the skin temperature. In this manner, merely an approximate estimate of blood flow to the extremity could be obtained, as the skin of the digit responds only slowly to the application of heat to the body. By means of the plethysmogram it has now become possible to ascertain the finer, often rapidly changing details of total blood flow to the digit. The data obtained through this simple, safe and painless method serve as a basis for the evaluation of the state of peripheral circulation, and permit an estimate of the probable outcome of lumbar sympathectomy.

The patients treated with indirect heat may be arranged into three groups: (1) Patients without arterial disease; (2) patients with organic arterial disease without ulceration of the extremity; and (3) patients with organic arterial disease with ulceration of the extremity. If possible, the degree of peripheral vasodilatation was studied prior as well as subsequent to lumbar sympathectomy.

Two double-sized electric pads were applied to the body of the patient. The vasomotor reactions following indirect heating were studied by means of continuous tracings of the plethysmograph as well as of the electronic recorder of skin temperature, while the relative blood flow to the toe was calculated at periodic intervals.

The plethysmogram was analyzed with special attention to the pulse wave which was recorded on photographic film traveling at the same rate of speed as that of the standard electrocardiograph, and also in relation to the alpha, beta and gamma waves, which were recorded on film traveling at the rate of four inches per minute. The relative toe flow was calculated from the slant of the base line of the plethysmogram, which in turn represented the rate of swelling of the toe following venous occlusion at the ankle.<sup>3</sup>

Among 20 normal individuals, resting in a comfortable environment, the pulse, respiration, alpha and beta waves occurred 76, 14, 6 and 1 times per minute, respectively. Gamma waves were observed at a frequency of less than one cycle per minute. A study of the plethysmogram of ten normal individuals at different body temperatures gave the following results: Body cooling was attended by lowering of the pulse, respiration, alpha, beta and gamma waves, combined with a reduced relative toe flow. Body heating, on the other hand, produced high pulse waves with a prominent dicrotic notch, combined with small alpha, beta and gamma waves, and an increase of the relative toe flow. Intermediate degrees of body heating resulted in pulse waves of variable amplitude and large alpha, beta and gamma

The influence of indirect heating upon a patient without arterial disease is presented in Figure 1. This patient, a 17-year-old girl, entered the hospital

because of edema of the legs of eight years' duration. A diagnosis of hereditary lymphedema was made. The arterial systolic blood pressure gradients, oscillometric readings and peripheral pulsations were normal. With the patient resting in a warm, comfortable environment (Figure 1-A) the pulse waves were of variable amplitude, and there appeared distinct modifications in digital volume. This variability is entirely normal for a slightly warm, relaxed individual. The filling and emptying of the toe with blood (alpha and beta waves—Figure 1-A) represent in all probability vasomotor changes normally occurring in the process of regulation of body temperature. The relative toe flow was 5.0 cu. mm. per 5 cc. per second. Body heating for 30 minutes (Figure 1-B) resulted in an increase in the amplitude of pulse waves and at the same time in a decrease in the amplitude of alpha and beta waves, indicating a high degree of vasodilatation. The relative toe flow rose to 21.5 cu. mm. per 5 cc. per second. Bilateral lumbar sympathectomy was performed against advice. The patient was again observed three years later, and the plethysmogram at that time (Figure 1-C) showed pulse waves of high amplitude, in combination with small alpha and beta waves; the relative toe flow was 13.0 cu. mm. per 5 cc. per second. These findings, especially the ab-

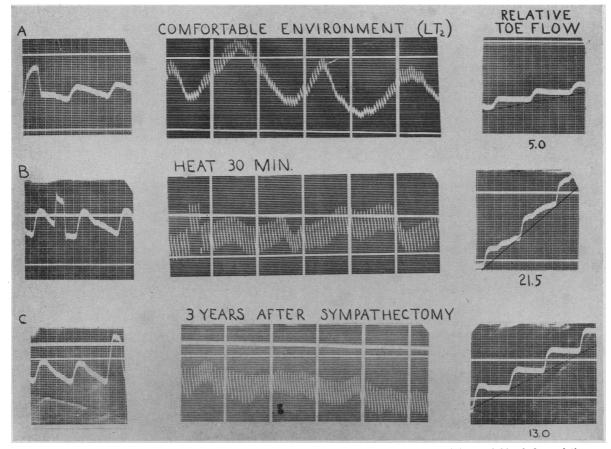


Figure 1.—Influence of body heating and lumbar sympathectomy on vasomotor activity and blood flow of the toe in a patient without arterial disease. Evidence of normal vasomotor activity suggested that lumbar sympathectomy would effectively increase the circulation to the extremity.

sence of spontaneous variations in toe volume, as apparent in the smallness of the alpha and beta waves, demonstrated that sympathectomy had been effective in decreasing vasomotor activity in the toes, and that this result persisted even after a period of three years.

Twelve patients with moderate arterial disease were examined by applying indirect heat, and in all instances it was found that lumbar sympathectomy resulted in moderate clinical improvement. This type of reaction is exemplified in Figure 2. A 34-year-old man with moderate arterial disease entered the hospital one and one-half years after fracture of the right leg. Examination showed definite skin changes with erythema and atrophy of the tissues of the toes. The right leg was three degrees cooler than the left. Pulsations in the right dorsalis pedis and posterior tibial arteries were absent. The plethysmogram of the second toe, right, with the patient resting in a comfortable environment, showed small pulse waves with little evidence of vasomotor activity. The relative toe flow amounted to 2.4 cu. mm. per 5 cc. per second (Figure 2-A). After body heating, the amplitude of the pulse waves increased four times and respiratory, alpha and gamma waves became apparent. The relative toe flow rose to 6.0 cu. mm. per 5 cc. per second (Figure 2-B). This increase in the amplitude of the pulse wave and the small increase in the relative toe flow together with the evidence of slight vasomotor activity suggested that moderate improvement could be expected from lumbar sympathectomy. An examination on the seventh postoperative day (Figure 2-C) demonstrated that the pulse waves were higher than they had been with the patient resting in a comfortable environment before body heating had been applied; the relative toe flow amounted to 5.4 cu. mm. per 5 cc. per second. Clinically the patient was moderately improved.

The influence of body heating upon the plethysmogram of patients with organic arterial disease and ulceration of the extremity was studied in eight cases in which lumbar sympathectomy was subsequently performed. The pattern of cases of this type is exemplified in Figure 3. The plethysmogram of a 58-year-old female with extensive arteriosclerosis obliterans of the popliteal artery combined with ulceration of the digits, made while the patient was resting in a comfortable environment, showed no pulse waves and no evidence of vasomotor activity. The relative toe flow was only 1.4 cu. mm. per 5 cc. per second (Figure 3-A). After 15 minutes of body heating, small beta waves were seen and the relative blood flow in the toe increased to 4.2 cu. mm. per 5 cc. per second (Figure 3-B). After 30 minutes of body heating vasomotor activity disappeared again.

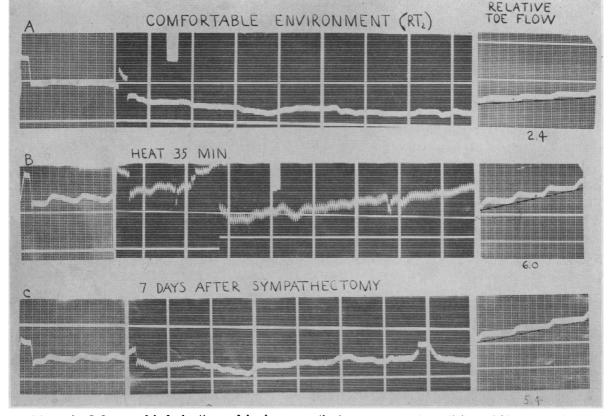


Figure 2.—Influence of body heating and lumbar sympathectomy on vasomotor activity and blood flow of the toe in a patient with moderate arterial disease following fracture of the right leg. Evidence of moderate vasomotor activity was present, and a fair degree of improvement was noted following lumbar sympathectomy.

and the relative blood flow in the toe decreased to 2.8 cu. mm. per 5 cc. per second, probably due to the borrowing-lending phenomenon<sup>5</sup> (Figure 3-C). These findings led to the conclusion that lumbar sympathectomy would not be of great help in this case. However, an operation was performed against advice. Plethysmographic studies, 30 days post-operatively, presented no evidence of vasomotor activity. The relative blood flow in the toe was only 3.0 cu. mm. per 5 cc. per second (Figure 3-D). As the patient's condition was not improved by lumbar sympathectomy, the leg had to be amputated three months later.

In none of the eight patients who, under the influence of indirect heating, produced a plethysmogram of this type did lumbar sympathectomy result in satisfactory clinical improvement. Subsequent amputation became necessary in two cases; one patient had an ulcer which refused to heal in more than

one year's time; in five other instances no essential changes were noted following lumbar sympathectomy.

On the basis of a comparison of the three types of plethysmograms with the therapeutic effect obtained in each group through lumbar sympathectomy, the following conclusion seems to be warranted: The appearance of large alpha and beta waves in the course of body heating indicates the presence of an active vasomotor response and suggests that lumbar sympathectomy may materially increase the blood flow through the digits. Conversely, the absence of these waves following body heating suggests that lumbar sympathectomy would be of little benefit.

#### DISCUSSION

Plethysmographic studies are of great aid in the proper selection of patients for lumbar sympathectomy. In this respect it is of special importance that

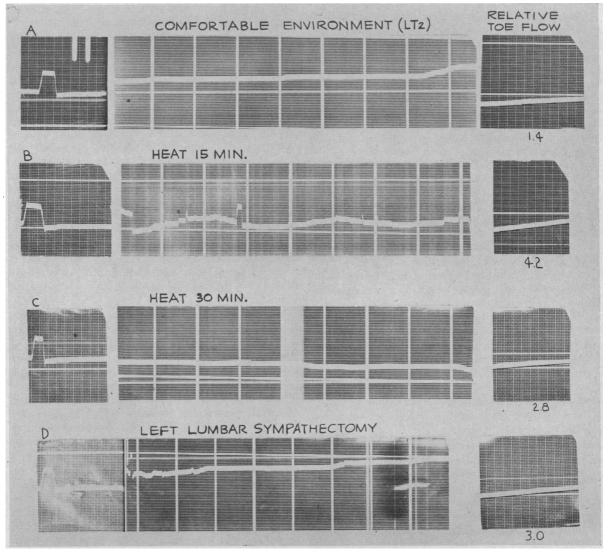


Figure 3.—Influence of body heating and lumbar sympathectomy on vasomotor activity and blood flow of the toe in a patient with advanced obliterative arteriosclerosis of the popliteal artery. There is little evidence of vasomotor activity and the results of sympathectomy were poor.

by this method it becomes possible to compare and evaluate the results obtained through various diagnostic procedures, as for instance arterial occlusion, ganglionic block, lumbar sympathetic block, spinal anesthesia, and indirect heating.

The plethysmograph is designed to measure the changes in the volume of an organ, and it is thus possible to estimate the total flow through that part, and not only the flow through the skin alone, as it is the case when merely the skin temperature is recorded. It happens occasionally that following lumbar sympathetic block the skin temperature of the digit rises while at the same time the plethysmogram remains essentially unchanged and the total flow, therefore, is not increased. Such findings suggest that under the influence of lumbar sympathetic block the distribution of the blood supply, but not the volume of the flow, has been modified, thus depriving the deeper tissues of the toe in order to increase the superficial blood circulation.

Many factors have to be taken into consideration in the interpretation of the plethysmogram, as identical wave forms may be due to entirely unrelated conditions. This applies especially to the psychic state of the individual. Tense, anxious, neurotic patients usually present plethysmograms with wave forms of low amplitude as well as a reduced volume of blood flow, characteristic of vasoconstriction. The plethysmogram of a relaxed, normal individual, at ease in a comfortable warm environment, on the other hand, shows large wave forms of variable sizes, indicating labile vasomotor activity. Transitory disturbances in the patient's environment such as irritating noises, drafts or chilling of body surfaces are likewise apt to produce low wave forms similar to those encountered in patients with organic vascular disease. In this case, however, differential diagnosis usually meets no great difficulties. Once these extraneous factors have been excluded, for instance through the application of heat to the body of the patient, the plethysmographic wave forms return to a normal shape, provided of course, the patient is not suffering from organic vascular disease. Sometimes the appearance of low wave forms can be traced to certain technical errors; faulty adjustment of the plethysmograph, for example, can lead to constantly substandard values, and a similar effect may also be brought about by incorrect measurement of the volume of the digit. Minor mistakes of this type are easily avoided by proper attention to detail.

By use of the plethysmograph it has become possible to evaluate the various diagnostic procedures available for the selection of subjects for whom lumbar sympathectomy may be of therapeutic benefit; but from the results obtained the conclusion is suggested that no one single method is applicable to all individuals. Among patients presenting relatively healthy tissue of the extremities without abnormal cutaneous sensitivity, the method of vasodilatation following arterial occlusion for a period not ex-

ceeding 15 minutes was employed with satisfactory results. In those cases in which peripheral vascular disease was still in its early stages, the increase in the relative rate of blood flow was rapid, indicating that lumbar sympathectomy could be expected to lead to pronounced improvement in the patient's condition. Because of tenderness or disease of the tissues of the extremity it was in many cases considered advisable to limit arterial occlusion to a period of five minutes. Increase of blood supply in the extremity following a shorter period of occlusion was smaller than when the flow had been arrested for a longer time. But when, after due allowance had been made for this discrepancy, it was found that the rate of blood flow had satisfactorily increased following arterial occlusion, lumbar sympathectomy was generally recommended. Yet, whenever the blood flow showed only a small increase after release of the occlusion cuff, it was decided that additional tests were required in order to obtain more definite data, and as a rule indirect heating or lumbar sympathetic block were instituted.

Evaluation of the effect of lumbar sympathetic block, as recorded in the plethysmogram, proved very helpful in the selection of patients for sympathectomy. This method, however, is not suitable for certain patients, especially debilitated or non-cooperative individuals or those sensitive to procaine. Skin resistance in the toe was carefully measured before, during and after infiltration of the sympathetic ganglia, in order to ascertain whether the lumbar sympathetic block had been successfully established. Whenever the plethysmogram demonstrates that the blood supply of the toe is considerably increased under the influence of lumbar sympathetic block, it may be expected that lumbar sympathectomy would be successful.

Of all diagnostic procedures applied, spinal anesthesia and ganglionic block using various agents proved least satisfactory. This finding is probably due to the fact that both methods lead to widespread vasodilatation.

Peripheral vasomotor activity can be conveniently analyzed after existing vasoconstriction has been relieved through indirect heating. Good results of lumbar sympathectomy may be expected in those cases in which, under the influence of body heating, the plethysmogram shows pulse waves of high amplitude with dicrotic notches, as well as prominent alpha and beta waves, combined with a high relative toe flow. Inasmuch as the alpha and beta waves are largely the result of sympathetic activity, it may be expected that whenever body heating leads to a greatly increased blood flow to the periphery, lumbar sympathectomy will produce a similar effect. With the progress of vascular disease a decrease in the amplitude of all waves in the plethysmogram is noted, especially during body heating, and at the same time the clinical improvement of the patient following lumbar sympathectomy is less striking.

The technical assistance of Grayce S. Fleming is gratefully acknowledged.

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## Correction

Table 2 in the article "Clinical Potassium Problems" which appeared in the March 1950 issue of CALIFORNIA MEDICINE contained an error. Item 6 in that table (page 136) under the heading "Mechanism of Shift in Potassium" read: "Shift from cells to serum with insulin therapy." It should have read: "Shift from serum to cells with insulin therapy."